contains said oxidizing gas with a fraction of 1 – [50] 20% by volume, and wherein said method further comprises the step, after said step of crystallizing said PZT ferroelectric film, of oxidizing said ferroelectric film in an oxidizing atmosphere.

REMARKS

A. Summary of the Office Action

Claims 1-2, 4-14 and 21-28 stand finally rejected under 35 U.S.C. § 103(a) as being unpatentable over *Cuchiaro et al.* (U.S. Patent No. 6,165,802) in view of *Solayappan et al.* (U.S. Patent No. 6,245,580) and *Ushikubo et al.* (U.S. Patent No. 5,851,841).

Claims 15-20 stand finally rejected under 35 U.S.C. § 103(a) as being unpatentable over *Izuhu et al.* (U.S. Patent No. 6,060,735) in view of *Duncombe et al.* (U.S. Patent No. 6,172,385).

B. Rejection Under 35 U.S.C. § 103(a) of Claims 1-2, 4-14 and 21-28 over the combination of *Cuchiaro, Solayappan and Ushikubo* Addressed.

Applicant respectfully traverses the rejections of claims 1-2, 4-14 and 21-28 over the combination of *Cuchiaro, Solayappan and Ushikubo*, and requests reconsideration.

As the Examiner correctly notes, *Cuchiaro et al* does not teach the step of thermal annealing process conducted in an atmosphere containing a non-oxidizing gas in addition to an oxidizing gas.

Solayappan teaches a process of forming an SBT film by a sol-gel process, followed by a baking process conducted in air. Specifically, the process is conducted in an atmosphere containing 21% oxygen, at a temperature of 800 °C for drying the film. After the foregoing process, an RTA process is applied to the dried coating in an atmosphere containing oxygen with a concentration exceeding the concentration in air at a temperature of 675 °C. This is done to burn out any residual organic components and to cause a nucleation process such that numerous crystal grains of the layered superlattice material are formed in the film. See column 8, lines 4-21 of *Solayappan*. *Solayappan* teaches that the presence of oxygen is essential in the baking process.

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Finally, a mixed atmosphere of oxygen and nitrogen is used in the furnace annealing process at a temperature of 700 °C or less for complete crystallization.

According to *Solayappan*, therefore, crystallization has already taken place in the RTA step 228 conducted in the oxygen atmosphere. Thus, the annealing step 230 of *Solayappan* is not in fact a crystallization process starting from an amorphous state as now claimed, but a recrystallization process started from an already crystallized state.

In the present invention, on the other hand, the crystallizing step starting from an amorphous state is conducted in an atmosphere containing oxidizing gas with a fraction of 1-20% in volume as set forth in amended claim 1. It is deemed that this clearly teaches away from the crystallizing step 228 of *Solayappan*.

Amended claim 21 of the present invention recites a two-step process. The second step of the process is conducted in an oxidizing atmosphere, which is different from step 230 of *Solayappan*. Process step 230 of *Solayappan* is conducted in an oxygen-deficient ambient.

Thus, Solyappan teaches away from the present invention and the subject matter of the present invention cannot be derived from *Solayappan* even if it is combined with *Cuchiaro*.

The method of *Solayappan* teaches the use of a sol-gel process. The film formed by such a sol-gel process contains substantial amounts of residual carbon, and because of this, there is a tendency for the crystal grains formed in the film to align in the desired (111) direction in conformity with the (111) orientation of the underlying Pt electrode surface. It is believed that the residual carbon in such an amorphous film reduces the difference of thermal expansion between the amorphous film and the underlying Pt electrode and the thermal stress applied to the film during the crystallization process is reduced.

In the case of a sputtered film as in the present invention, the sputtered film contains no carbon and there is a substantial tensile thermal stress in the amorphous film due to the difference of thermal expansion coefficient

between the sputtered amorphous film and the underlying Pt electrode. As a result of the tensile thermal stress, there is a tendency that the longer (001) axis of the Perovskite is aligned to the film surface and the shorter (100) axis is aligned perpendicular to the film when the sputtered amorphous film is crystallized at high temperatures in which a large thermal stress is induced. When this crystal orientation appears in the ferroelectric film, the film shows no ferroelectricity to the electric field applied perpendicularly thereto.

The present invention successfully overcomes the problem of crystal alignment in the ferroelectric film crystallized from a sputtered film. The method of the present invention achieves the desired (111) crystal orientation in the crystallized ferroelectric film by lowering the crystallization temperature, which in turn, is achieved by using an oxygen deficient ambient containing oxidizing gas with a fraction of 1 to 20% by volume as set forth in amended claim 1. As explained in the specification, there appears a non-columnar, two-layer structure in the crystallized ferroelectric film when the crystallization is conducted in a pure Ar atmosphere. Thus, the existence of oxygen of at least 1% in the ambient is highly desirable.

There is no teaching in *Solayappan* of conducting the crystallizing process of the ferroelectric film in an atmosphere containing an oxidizing gas with a fraction of 1-20% as set forth in amended claims 1 or 21.

With regard to dependent claims 2, 4-14 and 22-28, Applicant submits that the claims are allowable at least because they depend from and incorporate all the features of allowable claim 1 or 21, and for the same reasons that claims 1 and 21 are allowable. Accordingly, Applicant respectfully requests that the rejections of claims 2, 4-14 and 22-28 under 35 U.S.C. § 103(a) be withdrawn.

C. Rejection Under 35 U.S.C. § 103(a) of Claims 15-20 over the combination of *Izuha* and *Duncombe* Addressed.

Applicant respectfully traverses the rejections of claims 15-19 under 35 U.S.C. § 103(a) as being unpatentable over *Izuha* in view of *Duncombe* and requests reconsideration.

With regard to amended claim 15, it is noted that Izuha teaches the use of a Perovskite lower electrode, while the present invention uses a Pt-containing lower electrode.

In *Izuha*, the columnar ferroelectric grains grow continuously from the columnar grains of the lower Perovskite electrode, and there is a partial lattice matching between the conductive oxide forming the lower electrode and the columnar ferroelectric grains at the ferroelectric/lower electrode interface. See Diagram 1attached hereto.

In the case of the present invention, the crystallization of the ferroelectric film starts from the triple point of the Pt grains forming the lower electrode. This situation can be represented schematically in Diagram 2 attached hereto.

While *Izuha* teaches a grain diameter of 10-500 nm, the structure of Izuha is based on the use of an SRO conductive oxide for the lower electrode, and the grain size distribution in the ferroelectric film is predominantly determined by the grain distribution in the underlying SRO film. In other words, the microstructure of the underlying SRO film is transferred to the ferroelectric film grown thereon.

In the case of the present invention, the crystallization starts from the triple point of the underlying Pt layer. The mechanism of grain growth, particularly the mechanism for determining the grain size distribution in the ferroelectric film, is different from the case of forming the ferroelectric film on the SRO layer, and the teachings of Izuha cannot therefore be applied to the present invention.

The present invention successfully achieves the desired feature of "said PZT ferroelectric film having a columnar microstructure extending from an interface between said lower electrode and said PZT ferroelectric film in a direction substantially perpendicular to a principal surface of said lower electrode, said PZT ferroelectric film essentially consisting of crystal grains having a generally uniform grain diameter of less than about 200 nm" recited in claim 15 for the ferroelectric film formed on a Pt lower electrode by conducting

the crystallization process of the ferroelectric film first in the oxygen-deficient ambient and then in the oxygen ambient as set forth in claim 1.

Since the Office Action fails to establish a *prima facie* case of obviousness as to claims 15-19 for the reasons set forth above, Applicant respectfully requests that the rejection of claims 15-19 under 35 U.S.C. § 103(a) be withdrawn.

D. Conclusion.

Applicant respectfully requests the reconsideration and the timely allowance of the pending claims. Should the Examiner feel that there are any issues outstanding after consideration of this response, the Examiner is asked to telephone the undersigned to expedite prosecution. Please charge any fees associated with this transmittal to Deposit Account No. 50-1123.

Respectfully submitted,

May 3, 2001

Carol W. Burton, Reg. No. 35,465
Hogan & Harrison L.L.P.
1200 Seventeenth Street, Suite 1500
Denver, CO 80202
Telephone: (303) 454-2454
Facsimile: (303) 899-7333

ATTACHMENT

IZUHA

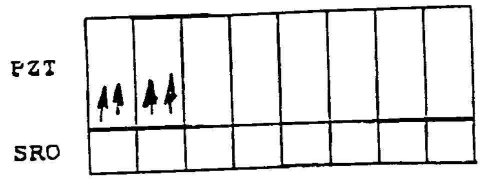

DIAGRAM 1

Present Invention

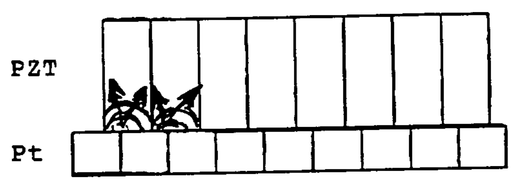

DIAGRAM 2